

## Data Center Redesign Yields an 80%-Plus Reduction in Energy Usage

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The National Renewable Energy Laboratory's (NREL's) data center is a showcase of energy efficiency and confirms many of Gartner's best practices in data center design. Most of what NREL has done can be replicated by clients; however, two design approaches are climate-dependent: near-full reliance on outside air for cooling, and photovoltaic arrays for power.

### Key Findings

- Four years ago, NREL's legacy data center had an estimated power usage effectiveness (PUE) of 3.3; the new facility averages 1.13.
- The techniques employed by NREL reduced energy consumption per user by an average of 81%.
- Most of the techniques employed by NREL confirm Gartner's best practices in data center design.

### Recommendations

- Accelerate virtualization plans and replace energy-inefficient servers as quickly as possible.
- Review your data center facility design; adopt our checklist of best management practices to the highest degree possible.
- Ascertain whether you are getting the largest advantage you can from the outside environment. If you are planning a new data center, examine in-depth how the local environment can help you achieve energy efficiency. Augment grid power with solar cells where economically viable.

## WHAT YOU NEED TO KNOW

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This Case Study demonstrates that significant energy cost savings and grid power usage reductions can be achieved via our best practices in data center design. NREL actually went beyond these practices and, due to its geographic location, employed more radical methods, such as full reliance on solar power and using outside air for nearly all its cooling needs.

## CASE STUDY

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### Introduction

NREL is the only U.S. federal government laboratory dedicated to the research, development, commercialization and deployment of renewable energy and energy efficiency technologies. NREL is in the process of building what they call "the campus of the future" in Golden, Colorado — a showcase of the use of renewable and energy-efficient techniques. For example, the entire campus is principally powered by five acres of photovoltaic arrays to achieve a net-zero energy use (that is, during the day, NREL provides excess energy to the grid, and at night, draws energy from the grid, with the result being the equivalent of no draw from the grid during a 24-hour period). Most of NREL's 2,200 employees will work on this new campus.

One of the completed buildings is the 222,000 square-foot Research Support Facility (RSF), a building meeting the Leadership in Energy and Environmental Design (LEED) Platinum certification requirements. Located within the RSF is the data center, which supports the business and administrative functions of the NREL. The new data center began operations in July 2010. Here, we focus on the energy saving techniques employed at NREL's data center.

### The Challenge

NREL recognized that the data center would be a major consumer of power. In building the RSF, NREL wanted to implement a data center that was as energy efficient as possible. When NREL embarked on this project, it was not in a good position; NREL's legacy data center had an estimated PUE of 3.3 — meaning that less than one-third of the power consumed went to the IT equipment. (PUE is simply the ratio of total power consumed to the energy consumed by the IT equipment.) Moreover, NREL sought to have the RSF (including the data center) operate on a net-zero basis with respect to grid power.

### Approach

NREL's approach was to essentially scrap the legacy data center and build a new one — a nearly complete replacement of the old data center. Sufficient time (three years) and resources (\$4.9 million) were allocated to this project. NREL aggressively adopted energy-efficient design principles for the new data center, and fully relied on solar power.

The following areas were addressed:

- **Servers:** NREL replaced nearly 90% of the legacy servers with more energy-efficient servers (in this case, the replacements were HP blade servers with variable-speed fans and very efficient power supplies). More than 80% of the data center's workload was virtualized, including 100% of Linux workloads and 80% of Microsoft Windows workloads. Linux and Windows servers deployed VMware software; additionally, all Solaris Unix servers were virtualized using containers. Only database and Exchange servers were not virtualized.  
A 23:1 ratio of virtual to physical machines has been achieved. In terms of power, 20

one rack unit (1u) servers, each drawing more than 300 watts, were replaced by one blade drawing 215 watts — more than a 10:1 power reduction. With virtualization, the average power consumed per virtual machine is less than 11 watts — nearly a 30:1 power reduction. What NREL accomplished with virtualized, energy-efficient servers alone should be a strong motivator for clients to retire old machines and to accelerate virtualization plans.

- **Cooling:** Heat generated via servers, storage and other equipment in a pod is captured via hot-aisle containment; the captured heat is then redistributed to where it can be effectively used within the building. Two pods are currently in operation (each holding 20 racks), occupying approximately one-third of the total data center floor space. Because the two pods have considerable expansion capability, extensive use was made of blanking panels to ensure proper air flow until the empty space was populated.

Given the climate in Golden, the outside air provides nearly all the data center's cooling needs. The custom-built cooling system features a large external air intake, high-efficiency fans and air filtration; no chillers are needed. "Free air" provides sufficient cooling for all but about 10 days a year — the hottest and most humid days. The ambient temperature of the data center was also raised from 68 F to 76 F. Additionally, the entire building uses a six-inch-high raised floor for airflow for additional cooling efficiency, and heavy use is made of weather stripping.

- **Uninterruptible power supply (UPS):** The existing 80%-efficient UPS was replaced with one that is 97% efficient at NREL's power load.

## Analyst's Observations

- What NREL accomplished in virtualizing energy-efficient servers should be a strong motivator to scrap old, legacy servers and virtualize to the fullest extent possible. Data center complexity, in terms of numbers of physical devices, has been dramatically reduced.
- Strong control of heat dissipation pays off — and this is a best practice that we have long advocated.
- We also certainly advocate the use of highly efficient UPS.
- Not all clients can make as much use of outside air as did NREL; however, most can at least use air economizers to reduce their power needs by 10% or so.
- Similarly, NREL's near-full reliance on solar power is not something most can have. However, it does demonstrate solar's ability to generate sufficient power for a large building. Alternative energy sources, such as solar, are expensive and, for now, will primarily be used where there are financial incentives or subsidies.
- Few clients have the luxury NREL had to essentially "take out a clean sheet of paper" and build their data centers from scratch. However, what NREL has accomplished points to the benefit of aggressive migrations to new data center designs.
- We see most new data centers using nonraised floors instead of the traditional raised floors (see "Do You Need a Raised Floor in Your Data Center?"). However, in this case, the data center is a tenant in the building and is making use of the facility. The raised floor supports air flow. Data center power and LAN cabling are above the racks, as is cooling equipment.

- It could be argued that having two pods with only a 52% occupancy is inefficient. However, recognize that this is a growth situation; the unoccupied rack space will be utilized short term. To accommodate future requirements and growth, there are also plans to build two more identical pods in the same area.
- NREL's objective was not to reduce costs. However, compared with traditional designs, it is certainly significantly less expensive (see Table 1).

**Table 1. Comparing Traditional and Best-Practice Data Center Design Costs**

	<b>Traditional Design</b>	<b>Best-Practice (NREL) Design</b>	<b>Comments</b>
Capital expenditure (capex; \$ million)	\$3.3 million	\$2.3 million	Capex is proportional to data center size (square feet); best-practice design uses 50% less space. (Note: This is an estimated facility cost only.)
Energy cost (per year)	\$450,000	\$280,000	Best practice design uses 60% less energy than traditional design.
15-year total cost	\$10 million	\$6.5 million	Capex + 15 x (annual energy cost)
15-year savings	NA	\$3.5 million (35%)	NA
Note: Because NREL's old data center had a very high PUE, we compare the new data center to a hypothetical traditional design. To simplify the analysis, we use average improvement levels from our data center model. We examine only the facility costs (i.e., non-IT), as the intent of this Case Study was to highlight the impact of best data center facility practices.			

Source: Gartner (August 2011)

## Results

- This was a very successful project — to the point that NREL is now advising other U.S. government agencies and departments on data center design.
- PUE was reduced from 3.3 to 1.15.
- Watts per user was reduced more than five-fold: 217 to 42 (for data center); data center power consumption was reduced from 516 kW to 93 kW.
- The project resulted in savings of \$330,000 in annual energy costs, and reduced carbon dioxide emissions by 5,000,000 pounds annually.
- Despite significant workload growth, floor space was reduced (from 2,500 square feet [100% occupied] to 1,900 square feet [52% occupied]) — considering rack occupancy, this is an effective reduction of more than two-to-one.

## Critical Success Factors

- Strong executive management commitment
- Sufficient budget and resources to get the job done
- Collaboration among IT and NREL researchers

## Lessons Learned

- Some technologies of interest were researched, but not deployed, due to lack of maturity or perceived high risk (for example, DC power distribution in the data center). Also, cloud computing was viewed as too immature for NREL's needs. NREL will be evaluating the use of cloud technologies for the possible delivery of commodity IT services.
- An energy-efficient data center is not enough; the NREL data center team is now turning to making operational processes more efficient via ITIL.
- The techniques employed can be replicated.

## RECOMMENDED READING

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*Some documents may not be available as part of your current Gartner subscription.*

"Shrinking Data Centers: Your Next Data Center Will Be Smaller Than You Think"

"What to Consider When Designing Next-Generation Data Centers"

"Now Is the Time: Replace Servers Early and Save Money"

"Energy Star for Data Centers: What CIOs Need to Know"

"Do You Need a Raised Floor in Your Next Data Center?"

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